



FLECH PowerMax Service Requirement Specification

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STRATEGIC PLATFORM FOR INNOVATION AND
RESEARCH IN INTELLIGENT POWER [IPOWER]

FLECH PowerMax Service Requirement Specification

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FLECH Power Cap Service Requirement Specification
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1 INTRODUCTION AND MOTIVATION

It is expected that in the future, ancillary services will be required at distribution level. This work describes how one of these ancillary services, the PowerMax service, must be specified within a market framework.

The basis of this work is the Flexibility Clearing House (FLECH) platform and the Distribution System Operator (DSO) services defined in [1]. The PowerMax service has been further discussed in [2], and this technical report seeks to clarify the implementation details first discussed in that paper.

The aim of the PowerMax service is to relieve congestion issues in the distribution system by establishing a maximum power that a cluster of consumer devices may draw from the system. The consumers will receive a payment for providing this service, and the DSO will be able to postpone grid reinforcement.

1.1 DISCLAIMER

This work focuses solely on the PowerMax service. Other services have been defined in [3] (the PowerCap service) and in [4] (the PowerCut service). Other issues regarding the implementation of FLECH and DSO services can be found on the iPower webpage. This document is written as a complement to [3].

1.2 INTRODUCTION TO THE FLECH MARKETPLACE

Fig. 1 is an illustration of the overall reason why a market place for flexibility is needed at the distribution level. The figure illustrates that the DSO on the one side is responsible for the distribution grid, knows the topology and the value associated with postponing grid reinforcements. However, the DSO's core competences are to maintain the distribution grid and not to understand consumers and enter directly into flexibility contracts with consumers.

On the other side are the owners of the devices with flexible consumption. Aggregators may be able to harness this flexibility and to enter into contract with the consumers. However, some platform is required to make the Aggregator able to meet with the DSO. The role of FLECH is to bridge the gap between the Aggregators with knowledge of the consumer device flexibility and the DSO with knowledge of the grid as illustrated in Fig. 1.

2 PLAYERS AND THEIR ATTRIBUTES

In the following section we introduce the main players in the considered setup. Note that this section is identical to the corresponding section in [3] except for some details in the description of FLECH.

2.1 DSO

Each DSO is responsible for sufficient capacity and adequate quality of delivery on the grid for which they are responsible. If the load in certain areas of the grid increases, the power capacity levels may be violated resulting in deteriorating or damaging the cables. Another issue is that the voltage may drop as the load increases, possibly outside the allowable limits which can cause problems for the consumers. The DSO is responsible for resolving such issues.

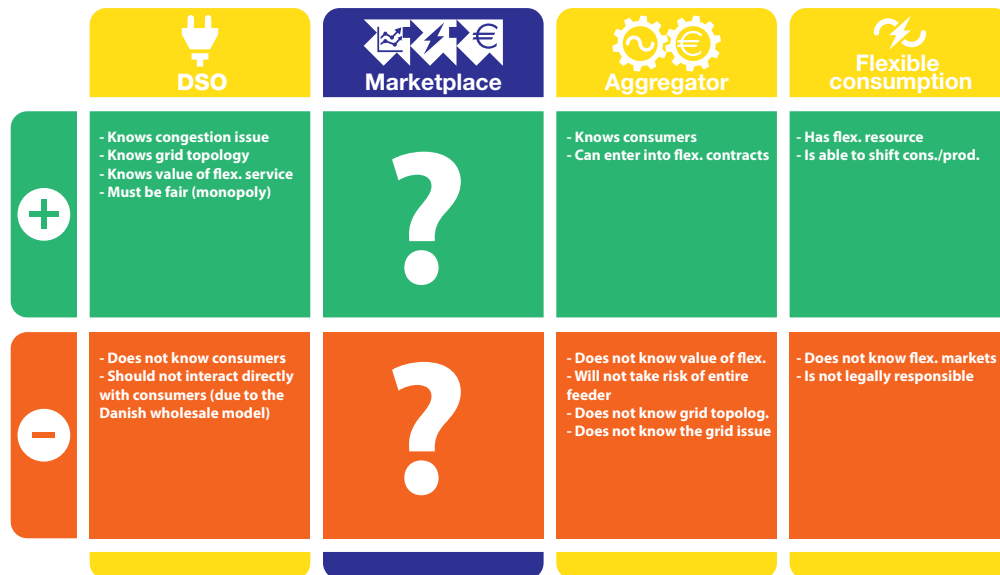


Figure 1: Overview of the roles of the actors.

Conventionally, such capacity issues are resolved via reinforcement. When the DSO discovers that there is a potential issue in the distribution grid, an analysis report is conducted describing the root of the problem, the possible solutions, and the associated costs. The solution may be replacing a low-capacity cable with a cable of higher capacity or it may be to install an entire new cable. Another option is to construct a new feeder to relieve part of the congested feeder.

The alternative to grid reinforcement is to shift load or to ensure production in certain hours of need in a market oriented framework as presented in [4]. The DSO will know the amount of flexibility that is needed, how many months of the year, and what hours of the day the flexibility is required. Based on this, the DSO can evaluate the value of postponing these investments by purchasing flexibility. For example, the DSO might observe that if the load during peak hours is reduced with at least 300 kW by one or several certain PODs (point of delivery), the voltage or power issues will be resolved.

2.2 FLEXIBLE CONSUMER OR DISTRIBUTED GENERATOR

Flexible consumption, such as thermal systems, lighting systems, pumping systems, etc., will be able to shift load in time depending on the device type. The owner of the consumption or production device will know the device's primary process and will know what flexibility can be offered and what the cost of offering this flexibility is. However, the owner of the device will often not have the know-how required to trade flexibility in the electricity markets or in FLECH. Moreover, the owner will not be a legal entity with the necessary bank guarantees or credibility to enter such markets.

2.3 AGGREGATOR

The Aggregator is an entity with the legal obligations and bank guarantees required to participate in the electricity markets and in FLECH. The Aggregator is expert in contracting flexibility with flexible consumers and distributed generation and utilizes the flexibility to generate revenue in the electricity markets [5].

2.4 TSO, INTRA-DAY, AND DAY-AHEAD MARKET PLACES

Flexibility in production or generation can today be sold in the transmission system operator (TSO) markets and the intra-day and day-ahead markets. In Denmark, the TSO-markets and the day-ahead markets are uniform price auctions where all the bidders will pay the same price for the electricity, while the intra-day market functions as a first-come first-served market.

2.5 FLECH

FLECH is a new element in the electricity system. Aggregators and DSOs can become players in FLECH by satisfying certain legal obligations. This allows the DSOs to submit flexibility requests to FLECH and the Aggregators to examine these requests and submit an offer if they are able to deliver the requested flexibility. See the reports [4, 6, 7].

Note that in this work, contrary to [3], the functionality of FLECH includes market clearing in the case where several Aggregators submit bids to the same tender.

3 INTERACTION OF PLAYERS TO DELIVER A POWERMAX SERVICE

In this section, we present the relationships and interactions between the players described in Sec. 2.

3.1 DISTRIBUTION GRID FLEXIBILITY MARKET

In the reports [3, 4] different assumptions have been made regarding the flexibility market for the distribution grid ancillary services. While some of the assumptions made here are close to those presented in [3], there are some fundamental differences, specially with regards to how the services are contracted.

In this report, we examine the case where the DSO forecasts an issue that must be resolved by grid reinforcement, e.g. the overload of a feeder or a transformer. The issue only appears periodically, e.g. weekdays from 17:00 to 19:00 during the winter months.

The tender is sent to FLECH and is responsible of announcing the tender to the relevant Aggregators. It will receive the bids from the Aggregators, and clear the market. Finally, after the service delivery, it will handle the settlement transaction.

While [3] assumes that the geographical location constraint will lead to cases where only one Aggregator will be available for service provision, in this work we assume that there will be two or more Aggregators available and willing to provide ancillary services. Each Aggregator will be able to bid their flexibility in a public auction to FLECH, which will clear the market in a similar manner to the market clearing defined in [4]. Further details of this process are given in Sec. 4.2

At an overall level, FLECH has to facilitate several functional steps for the new DSO service:

- FLECH is an easy way to make DSO flexibility requests visible for all Aggregators and thus eases the DSOs' and Aggregators' efforts to find trading parties.
- The DSOs are monopolies and must act fair to all consumers. Therefore, it may be controversial for a DSO to enter directly into a flexibility contract specifically with a certain consumer because this may look like the DSO is favoring this particular consumer. Letting the DSO offer the flexibility request to FLECH is a way to make flexibility trades fair and transparent and to avoid suspicion of favoring certain consumers. This point is also reinforced when it is FLECH clearing the market, and not the DSO.
- FLECH will clearly state what legal obligations the participants should fulfill to participate, for example certain bank guarantees. This ensures compensation in case of companies going bankrupt etc.
- FLECH specifies a standardized [8] way to submit flexibility requests and thus makes it much easier and cheaper for Aggregators and DSOs to enter into agreement.

3.2 OVERVIEW OF PLAYERS INTERACTIONS

In the following, the interaction between the different players is described. The overall architecture is illustrated in Fig. 2. Note that this subsection is identical to the corresponding one in [3].

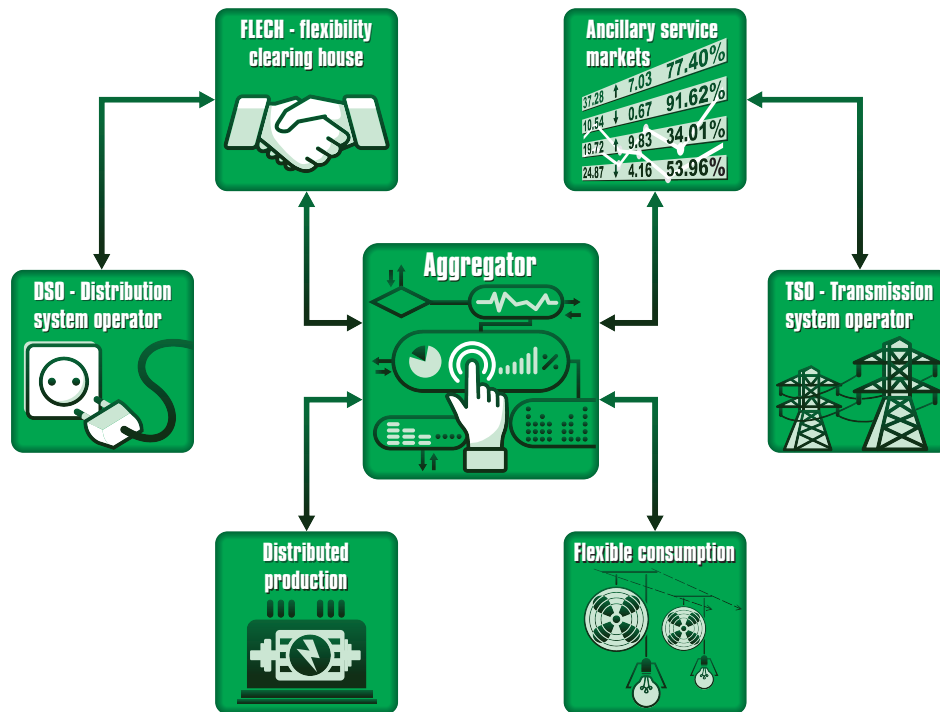


Figure 2: Overview of the interaction between the different players.

3.2.1 AGGREGATOR AND CONSUMERS

The Aggregator is specialized in entering into contracts with distributed production and flexible consumption. Different types of contracts can be made between the Aggregator and the owner of such devices [5], but the main concept is that the Aggregator is allowed to utilize the devices' flexibility under certain constraints and at a given cost.

3.2.2 AGGREGATORS AND THE ANCILLARY SERVICE MARKETS

The objective of the Aggregator is to maximize the value of its portfolio of flexible devices. The Aggregator can do this by participating in different markets, for example the ancillary service markets, but it could also be the two energy exchange markets, i.e. the day-ahead and intra-day markets.

3.2.3 AGGREGATORS AND FLECH

The Aggregator can also participate in FLECH to further increase the value of its existing portfolio. The Aggregators can keep an eye on FLECH concerning business opportunities and hereby for example examine if DSO requests are made in the areas where the Aggregator manages flexible devices. If this is the case, the Aggregator may be able to

utilize the equipment already installed at these devices to deliver the service specified by the flexibility request in FLECH. Another option is that the Aggregator sees an offer in FLECH at a geographical location where the Aggregator does not manage any flexibility. In this case, the Aggregator can examine if there is available flexibility in that given area and if it is economically attractive to include these devices in its portfolio.

3.2.4 FLECH AND DSOs

The DSOs are able to submit demand requests to FLECH.

4 TRADING SPECIFICATION OF THE PROPOSED POWERMAX SERVICE

In this section, we clarify how the DSO expresses its service needs, and the Aggregator/FLECH/DSO interactions needed for service provision.

4.1 THE PROBLEM

Based upon historical data, a DSO forecasts a load profile that will lead to a congestion problem in its grid. For example, a transformer can be overloaded every week-day during the months of November, December and January, between 17:00 and 20:00. The DSO has two options to solve the problem, either reinforce the grid, or acquire a congestion management service from the units operating in the congested zone. From a planning perspective the safest option is grid reinforcement, yet this is also an expensive solution. Reinforcement also has the added risk of over-dimensioning, e.g. in the case where after only a few years of the reinforcement being made, the load on the feeder is reduced due to improvement of energy efficient technologies, or due to a large consumer closing down. This could lead to a late return of investment, if at all.

The alternative to reinforcement is to acquire a service from one or more Aggregators, who will control their unit portfolios in such a way that the system performs within safe operation limits, e.g. the estimated peak load \hat{P}_{tot} on a transformer is reduced to be within normal operation. In this document we analyze specifically the PowerMax service [1], which solves the congestion problem by putting a limit to the maximum load of a set of Aggregators during the congested time span. This is illustrated in Fig. 3, which shows an example of the congestion problem over one day. By utilizing the flexibility of the Aggregators, the DSO is able to avoid the congestion on the transformer at a cheaper price than grid reinforcement.

The challenge in this case is for the DSO to formulate an adequate service tender that will solve the congestion issue. In order to formulate the service tender, the DSO must separate the load forecast over the congested time period into controllable load (CL) and a base load (BL):

$$\hat{P}_{tot} = \hat{P}_{CL} + \hat{P}_{BL} \quad (1)$$

$$\hat{P}_{CL} = \sum_{Agg} \hat{P}_{CL,Agg} \quad Agg \in \mathbf{A} \quad (2)$$

where \mathbf{A} is the set of Aggregators in the congested area. It is important to note that controllable consumption refers to the consumption by loads that are in contract with an Aggregator and can deliver services. Other flexible loads that are not in an Aggregator portfolio are considered part of the base load.

Now Aggregators must be contracted to deliver a reduction in consumption, ΔP , so that the overall peak load remains within operational limits denoted by \bar{P}_{sys} :

$$\hat{P}_{BL} + \hat{P}_{CL} - \Delta P \leq \bar{P}_{sys} \quad (3)$$

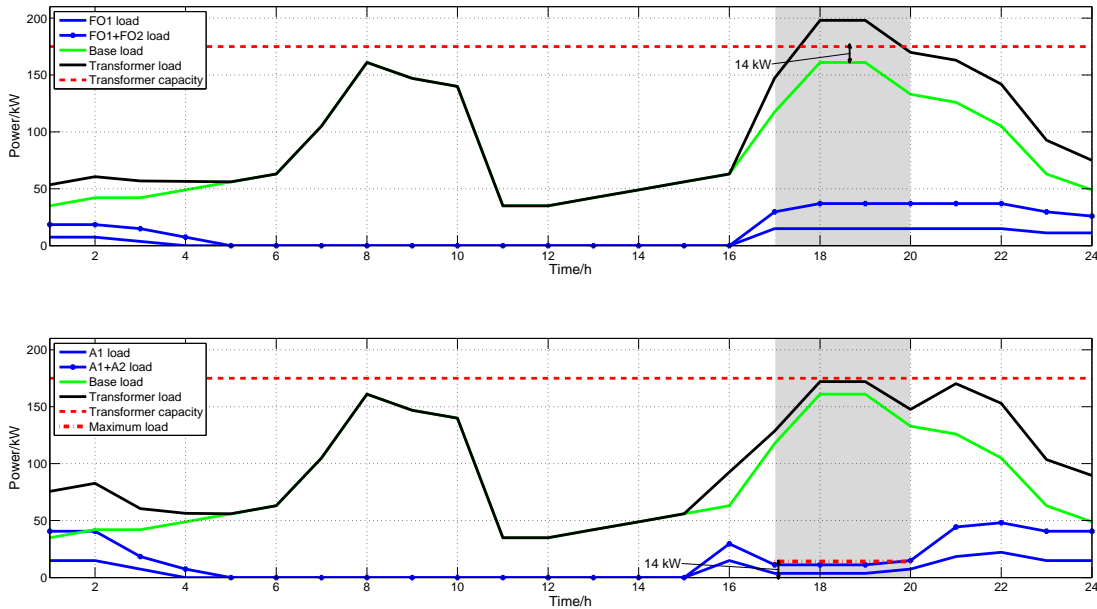


Figure 3: A scenario where the forecast of a transformer load indicates an overload situation during hours 17:00 to 20:00. A limit of 14 kW on the flexible load, managed by the Aggregators A1 and A2, is able to solve a congestion issue on a transformer [2].

where \hat{P}_{BL} is the estimated peak base load, and \hat{P}_{CL} is the estimated peak controllable load. In Fig. 3 the \bar{P}_{sys} is the nominal transformer capacity.

From Eq. (3), it is clear that the DSO needs to set a peak limit \bar{P}_{CL} such that:

$$\bar{P}_{CL} = \hat{P}_{CL} - \Delta P \quad (4)$$

The specific needs of the DSO, ΔP and \bar{P}_{CL} , are expressed in Eqs. (3)-(4). In order to formulate a service tender, the values of these needs must be estimated taking into account the uncertainty of the forecasts, giving the following expressions:

$$\Delta P_{DSO} = \sum_{Agg} \Delta \hat{P}_{CL,Agg} + \text{Risk}\{\hat{P}_{CL} + \hat{P}_{BL}\}; \quad Agg \in \mathbf{A}_c \quad (5)$$

$$P_{max,DSO} = \hat{P}_{CL} - \Delta P_{DSO} \quad (6)$$

where $\Delta \hat{P}_{CL,Agg}$ is the estimated power reduction the individual Aggregators will bid, $\text{Risk}\{\hat{P}_{CL}\}$ is the uncertainty of the load forecasts, and $\mathbf{A}_c \subseteq \mathbf{A}$, i.e. \mathbf{A}_c is the subset of Aggregators that bid into the market. Eq. (5) means that the DSO asks for a reduction in consumption ΔP_{DSO} that derived from an estimate of the total reduction the Aggregators will bid, accounting for Aggregators not bidding all of their flexibility (or some Aggregators not bidding in at all), plus a risk value that covers the uncertainty in forecasts. E.g. in Fig. 3, $P_{max,DSO} = 14 \text{ kW}$ and $\Delta P_{DSO} = 23 \text{ kW}$.

Having identified a suitable $P_{max,DSO}$ and ΔP_{DSO} to solve the congestion issue, the DSO formulates a tender to acquire a PowerMax service. Following the standard procedure in the power system, acquiring DSO services is divided into four phases:

1. Planning
2. Scheduling
3. Operation
4. Settlement

The information exchange and timing can be seen in Fig. 4. In this report we focus on the details necessary for the

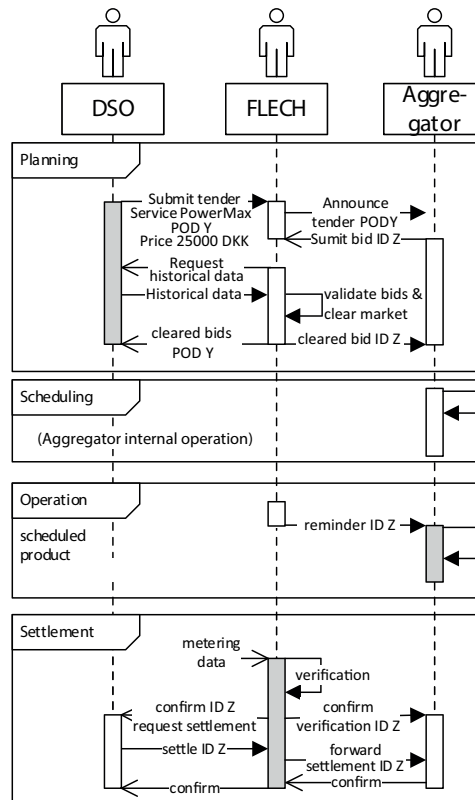


Figure 4: A general sequence diagram for the DSO/FLECH/Aggregator interactions[2]. The PowerMax service is a scheduled service and has a simpler operation phase than the PowerCut service presented in [4]. POD Y covers the area where the service is required, and bid ID Z is the identification number of the submitted bid.

planning phase to operate. This phase can be split into three steps: the DSO tender announcement, the Aggregator bid for the service, and the clearing of the market. Each of these steps are discussed below.

4.2 DSO TENDER ANNOUNCEMENT

The DSO must express its need for limiting the power consumption from the flexible units in the congested zone. The method for defining the tender is under discussion, but here we propose the following steps:

1. An Aggregator willing to participate in the DSO service market must register with FLECH as stipulated in [6].

2. When the DSO forecasts its need for flexibility it formulates a tender for the service and sends it to FLECH. The DSO formulates its tender with the following information:
 - (a) The amount of power reduction from an expected consumption rate (ΔP_{DSO}) to new limit ($P_{max,DSO}$), e.g. from peak load 37 kW to $P_{max,DSO} = 14$ kW ($\Delta P_{DSO} = 23$ kW) as seen in Fig. 3.
 - (b) A list of PODs describing the area where the service is needed.
 - (c) A maximum price the DSO is willing to pay for the service. The maximum value of the price equals the cost of reinforcement minus administrative overheads for the service acquisition and minus a risk value. This price is only for internal use of FLECH for the clearing of the market.
 - (d) The time variables for the service provision:
 - Which months/days the service is to be delivered.
 - Start and end time of service delivery.
 - The time from the start of service delivery within which the service must be delivered fully.
3. FLECH then announces the tender to the Aggregators under the relevant PODs.

Four assumptions are made in order to make this setup possible:

- The DSO has enough grid measurements and data to do accurate load forecasts.
- The DSO is able to separate the load forecast of transformers/feeders into controllable consumption and a baseload. This separation is done through analysis of historical metering data for the POD and standard consumer profiles. The DSO is able to use the load forecast to estimate how much the peak consumption on a transformer/feeder needs to be reduced.
- There is a standardized method to forecast load consumption that both DSO and Aggregator can agree upon. This is necessary so that the bids made by the Aggregators match the tender, i.e. both parties agree on the ΔP of the Aggregator bid. It is the responsibility of FLECH to publish the standard method for the forecast of the maximum load.
- The DSO must be willing to absorb the risk of continued congestion issues due to:
 - Inaccuracies in the controllable load forecasts.
 - Inaccuracies in the base load forecasts.
 - Aggregators not bidding their full flexibility (or not bidding at all), leading to an only partially mitigated congestion.

Furthermore, in case the market is not cleared, the DSO can formulate a new tender, adjusting the risk value, POD list or amount of power reduction. In this way, the service acquisition can become a negotiation.

4.3 AGGREGATOR BID

Aggregators bid for the service, expressing the load limit as a reduction from what expected normal operation would have been for its portfolio. That is, the Aggregator estimates its own peak consumption in the service delivery period, and states how much it can reduce that peak consumption, ΔP_{Agg} , to a new load limit $P_{max,Agg}$. The bid from the Aggregators must contain the following information:

1. Aggregator ID and POD.
2. Offered $P_{max,Agg}$ and ΔP_{Agg} , e.g. a reduction of $\Delta P_{Agg} = 15 \text{ kW}$ to the new limit $P_{max,Agg} = 5 \text{ kW}$.
3. A price for the service.

This bid is sent to FLECH before market closure. It is important to point out that the Aggregator is aware that there is a limit to the price it can ask for, and will bid within this limit if possible. As explained in Section 4.2, there is a possibility of negotiation in case the maximum price of the DSO is too low compared to the price the Aggregator can bid.

4.4 MARKET CLEARING

The market clearing is the responsibility of FLECH and occurs in two steps. In the first step the bids are validated by comparing the proposed reduction of the Aggregators to the load forecasts of FLECH. These forecasts are done by FLECH following the same forecast method assumed in Section 4.2. A bid is validated if the maximum load of the Aggregator ($P_{max,Agg} + \Delta P_{Agg}$) deviates from the peak forecasted by FLECH with less than a calculation error tolerance. The calculation error tolerance is defined beforehand by FLECH and could be, for example, of 1%. This calculation error tolerance is not to be confused with the allowable service delivery error defined in [1]. The validation of a bid requires further communication between FLECH and DSO, since FLECH must be informed of the relevant historical data measured by the DSO.

In the second step, FLECH clears the market according to the cheapest service bid.

The market clearing is done according to a merit order list of the validated bids. Usually the cheapest bids are accepted, as seen in Fig. 5, although it is possible that FLECH overrules the merit order principle in cases where a subset of more expensive bids can fulfill the requested volume at a lower price, as seen in Fig. 6.

4.5 SCHEDULING, OPERATION AND SETTLEMENT

The scheduling phase of the service consists of the Aggregator's internal operation. Depending on the Aggregator architecture, the Aggregator will take necessary steps to ensure that its portfolio operates in accordance to the PowerMax service delivery.

As shown in Fig. 4, the PowerMax service is a scheduled service which does not require an activation signal. It is expected that the Aggregators will activate their service provision as stated in the contract. If the service provision was executed without problems, FLECH will facilitate the economic settlement between the parties, as illustrated in Fig. 7.

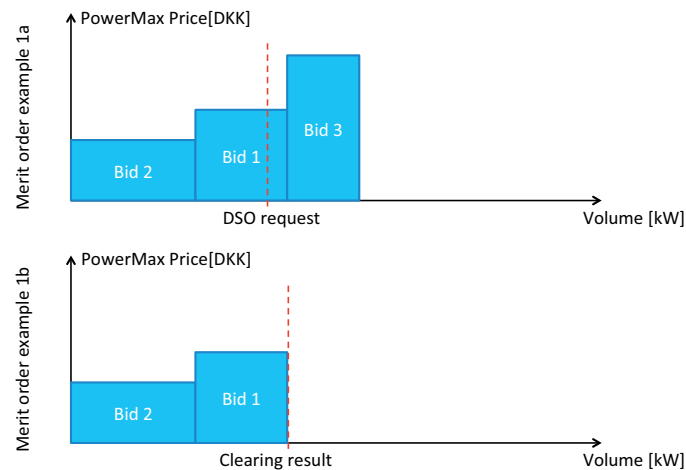


Figure 5: First market clearing case, where the cheapest bids, Bid 1 and Bid 2, are selected to provide the PowerMax service. It is likely that the clearing result exceeds the requested DSO capacity. If this becomes an issue, the DSO must specify maximum and minimum block bid sizes.

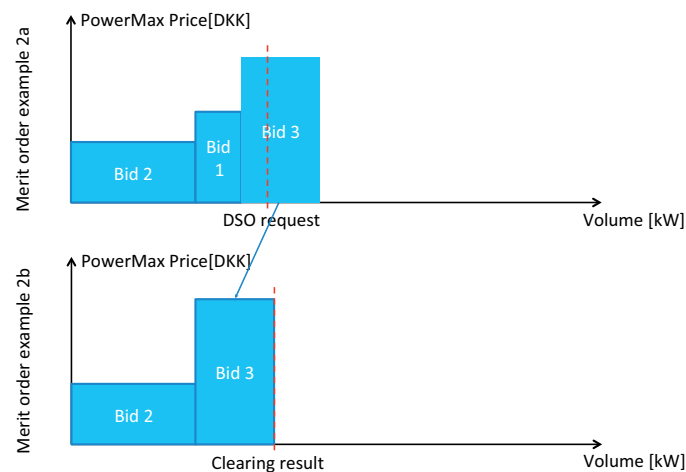


Figure 6: Second market clearing case where, due to the volume of the bids, it is cheaper to contract Bid 2 and Bid 3, although Bid 1 is cheaper than Bid 3.

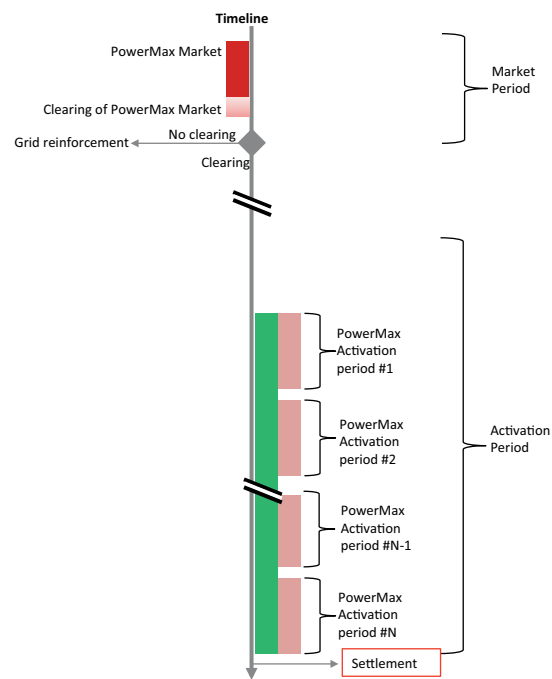


Figure 7: The PowerMax service is requested months ahead of its need. If the market is not cleared, i.e. no Aggregator is willing or capable of providing the service to an appropriate price, the DSO will invest in reinforcement of the grid.

5 CASE STUDY

As part of a reviewing process of the state of their distribution grid, a DSO updates the load forecast for a transformer in their distribution grid. As presented in Figure 8 (top), the DSO estimates that the load on the transformer will exceed the nominal operation capacity of 175 kW during peak load hours, i.e. from 17:00 to 20:00, on weekdays from November to February. Utilising the standardised load forecast provided by FLECH, the DSO analyses the share of controllable power consumption relative to the desired reduction. From this, the DSO estimates that there will be sufficient controllable consumption available to reduce the total load to below nominal maximum operation capacity. After an evaluation of the cost of grid reinforcement compared to acquiring demand-side management (DSM) services, the DSO decides upon the acquisition of DSM services. The PowerMax service is chosen, thereby setting a maximum limit on the power consumption from flexible loads connected to the transformer.

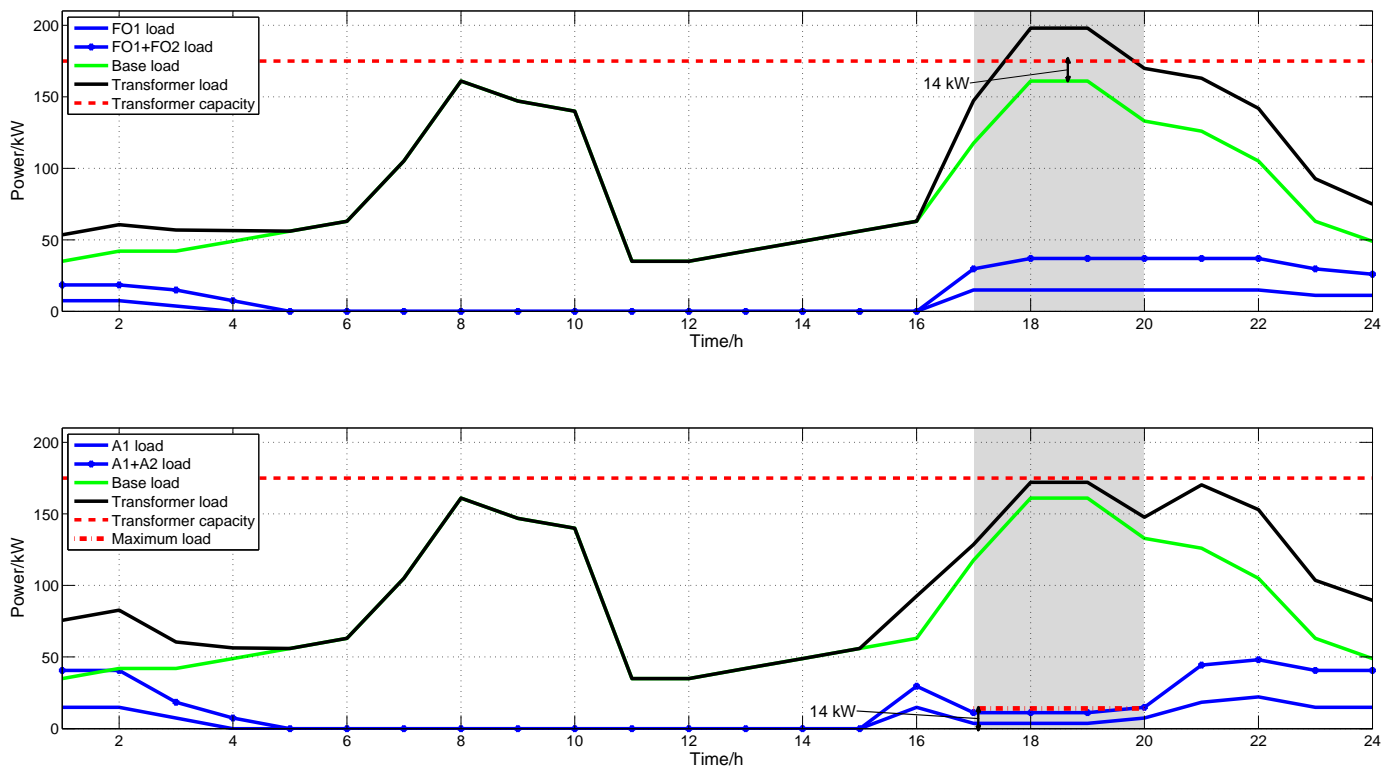


Figure 8: Reproduction of Figure 3.

Since the feeder in the DSO's distribution area is limited to maximum operation of 250 kW, the load during normal operation should not exceed 175 kW, i.e. 70% of the operation capacity.

From the load profile, as presented in Figure 8 (top), the DSO identifies problems with overload in the hours from 17:00 to 20:00 (greyed area), during the weekdays of the four months of wintertime. Consequently, the DSO decides to open a tender for a reduction of the controllable loads connected to the transformer. In the period from 17.00 to 20.00, the DSO formulates a tender (T1) for a reduction of flexible loads from 37 kW of total controllable consumption, as estimated from the standardised baseline, down to a PowerMax limit of 14 kW, i.e. $P_{max,DSO} = 14 \text{ kW}$ and $\Delta P_{DSO} = 23 \text{ kW}$.

The tender is announced to FLECH, which then notifies the relevant Aggregators. Two Aggregators, i.e. Aggregator 1 (A1) and Aggregator 2 (A2), are available in the DSO's distribution grid to deliver the requested service and are therefore eligible for making offers for the requested service. A1 submits a bid to FLECH for a reduction of its flexible loads from 14.8 kW to 3.7 kW (B1) at a price of 10.000 DKK. Likewise, A2 submits a bid for a reduction from 22.2 kW to 7.4 kW (B2) at a price of 20.000 DKK. FLECH validates the bids by comparing them to the standardised baseline and clears the market based upon the lowest price achieved by the merit order principle. The resolved winning bids are both B1 and B2. Following, FLECH notifies the Aggregators about the winning and potentially rejected bids, and similarly the DSO about the fulfilment of their tender.

At the time of service delivery, FLECH notifies A1 and A2 about their obligations to provide down regulation of the loads. Subsequently, during the operational phase, A1 and A2 delivers the load reduction as specified by their individual bids. Following the operational phase, FLECH verifies the services that A1 and A2 delivered during the service period, using local measurements from the relevant PODs. Following the verification process, FLECH notifies the relevant players, i.e. the DSO, A1 and A2, about the successful service validation and a payment notification is sent to the two aggregators and an invoice is sent the DSO.

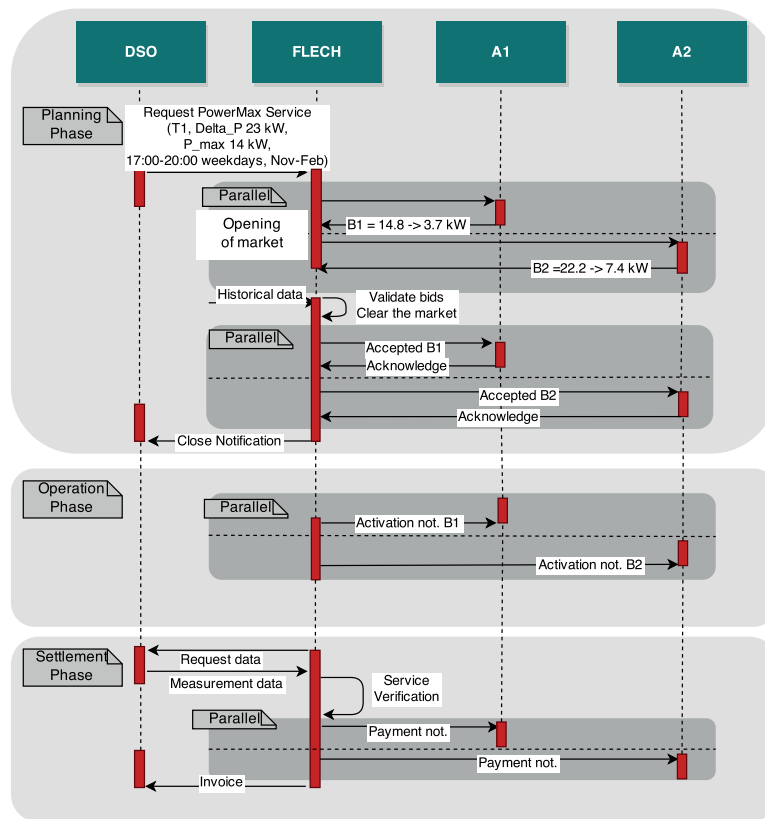


Figure 9: Message Sequence Diagram for the study case with 2 Aggregators bidding for a PowerMax service.

6 CONCLUDING REMARKS

This report describes how the DSO in cooperation with FLECH can formulate a tender for acquiring the PowerMax service. The purpose of this is to solve some of the questions arising from the practical implementation of the PowerMax service which are not addressed in [1, 2].

Although this report is similar to [3], it presents a more theoretical analysis of the presented service. The scope of the report is not to present the economical viability of the service, but rather what are the practical requirements to make the PowerMax service viable as a service within a market frame. This opens for the possibility of two or more Aggregators being able to deliver fully or partially the required service. Furthermore, in this case FLECH acts as an entity that facilitates the needed market transactions.

Although the conceptual description of the PowerMax service presented in [1] is relatively simple, adapting the service to the market framework with FLECH in between Aggregators and DSO rises some questions with regards to the feasibility of implementation of the service. We have tried to provide a solution to these questions in section 4, which goes into detail regarding the assumptions and requirements for the PowerMax tender formulation and bidding.

6.1 FLECH MARKET DISCUSSION

An aspects that has not been touched upon in this document, is the market conditions under which FLECH operates. Due to the low number of expected Aggregators operating in a market area, i.e. under a given POD, the market is far from perfect; most likely, only one Aggregator will be available to deliver a requested service at a single POD. Thus assumptions of a perfect market cannot be applied and hence should be taken into consideration when designing a market platform like FLECH. A non-perfect market can be a problem, when one market player can exploit another player. In the FLECH market set-up, there is only one buyer of a given service, i.e. the DSO, and potentially only one service provider, i.e. Aggregator. If for instance an Aggregator is able to estimate the value of a requested service, he can place his bid just below such that he is almost certain to be activated. In this way, he will be able to receive a payment that is significant higher than the marginal cost of the service he is providing. Furthermore, an Aggregator can benefit from shifting his controllable load to periods of peak demand, when he is not providing any service to the DSO, thus increasing the daily peak load and the likelihood that his services will be needed in the following period. In this way, the Aggregator can create a need for services that might have been unneeded otherwise. By use of game theory, an intelligent Aggregator could optimise the long term operation of his portfolio, by "manipulating" the baseline to appear as if demand response services are needed. An argument against Aggregators taking advantage of their role is that if the Aggregator keeps on exploiting the DSO, the DSO might choose to grid reinforce and thus making the services from the Aggregator obsolete and consequently the Aggregator will be *out of business*.

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